A STUDY ON CAUSES AND CONTROL OF CRACKS ON AUTOCLAVED AERATED CONCRETE MASONRY UNIT.

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Abstract : Autoclaved aerated concrete blocks are light in weight and density varies from 450-950 kg/Cum, that reduces the dead load of the main structure and have better earthquake resistance, have high compressive strength, has better moisture resistance, have better sound insulation property and absorbs less water, has better fire resistance and available in big blocks and requires less mortar, therefore it increases the speed of construction, so economical too when it is compared to conventional clay bricks. But, the AAC blocks show cracks on the surface due to loading, change in temperature, provision of reinforcement and seismic zoning, and in this paper, a study is carried out to reduce the crack formation and solutions to reduce or to eliminate the crack.

Index Terms - **Autoclaved aerated concrete block, loading, temperature, reinforcement, cracks resistance.**

I. INTRODUCTION

Autoclaved aerated concrete brick is lightweight, environment friendly, thermal resistant, sound insulator, water conversant, highly workable, fire resistant, moisture resistant and resistant to freezing & thawing. It is a very good replacement of ordinary brick. Apart from these properties it has same strength as ordinary brick in less cost thus it is economical also due its light weight it is helpful in reducing dead load of structure also it is helpful in developing heat resistant structure in cold region such as Europe, Russia etc.it is also helpful in making our structure more fire resistant.it also use in highly sound polluted area to make structure sound insulated.

Apart from positive side there are some performance-based improvements are required as the AAC blocks shows cracks on the surface due to loading, change in temperature, provision of reinforcement and even seismic zone and some researches shows positive results when it is treated with CRPF strips, bamboo… and analytical study also carried out to study the crack formation and solutions to reduce or to eliminate the crack.

II. CAUSE OF CRACK FORMATION

1) Load bearing

Load bearing is one of the causes for crack formation in AAC block and to determine the influencing factors for the cause numerical calculations were conducted and they showed that with extreme self-weight loads, imposed loads, environmental and rheological loads the corner of the walls was exposed to the damage. At different level of loads and different geometry of walls the size of shrinkage deformations, by which the crack formations in the area of intersecting loadbearing walls will not take place was given. The influencing factors for typical crack formation in AAC masonry wall were determined by using FEM and computational analysis.

2) Temperature

Autoclaved aerated concrete (AAC) blocks due to their light weight, low density are extensively used as masonry units in construction in spite of these properties there exists a problem of cracking in the AAC units under high temperatures, It is also said that the blocks undergo thermal expansion. The plaster does not get adhered to the surface of units. An effort has been made to determine the strength behaviour, bond behaviour, crack behaviour and thermal behaviour of AAC blocks under varying temperatures, mortar ratios and thickness. It is found that there was reduction in the strength and formation of cracks for temperatures above 500 deg C, the bond behaviour was found vary with mortar thickness and ratios. Thermal comfort study showed better thermal comfort in comparison with the model with Solid Concrete Block.

III. CRACK CONTROL EFFORTS

1) Reinforcement

The experimental tests are conducted on masonry walls in full-scale made of autoclaved aerated concrete masonry units. The walls were unreinforced and reinforced. The reinforcement in form of steel wire, glass, and basalt fibre meshes was applied in each masonry bed joint. The walls were subjected to simultaneous incrementing vertical loads and deflection of the structure which they are supported on. The carrying capacity of reinforced walls was up to 1.5 times higher than unreinforced walls. Test results of reinforced walls also showed lower values of deformation angles in relation to the walls without reinforcement for given load and deflection of support. In case of reinforced walls, much smaller widths of the cracks were obtained. The reinforcement allows to keep integrity of walls even after reaching the maximum load and deflection of supporting structure. The paper describes cracking and damaging mechanism of the walls as well.

2) CFRP Strips

In modern architecture, especially in dwelling buildings, one of the most popular and frequently used materials for construction of load-bearing walls are AAC blocks with thin layer joints. Such type of masonry units is recommended for construction of masonry walls with unfilled head (horizontal) joints. Construction speed using this technology is higher and brick work is easier. Unfortunately, there is also a negative aspect of unfilled head joints: such walls are characterized with low crack resistance, especially in case of shearing loads. This is a common problem in the buildings located in the areas of seismic influences, but also, in buildings subjected to uneven settlements. One of the solutions to improve the crack resistance of the masonry walls made of AAC blocks is application of superficial strengthening using CFRP mats. This paper presents the results which investigated the effectiveness of strengthening with carbon fibres strips in different assembly configurations. Three series of masonry specimens were used: strengthened wallettes, small rectangular walls with strengthening on both sides with strips mounted on the surface and covering the head joints, and specimens with strengthening also on both sides but with CFRP strips mounted outside of the head joints. All specimens were subjected to diagonal compressive loading according to RILEM LUMB 6 recommendations. An increase of shear capacity of both types of strengthening with respect to the unreinforced elements was observed. In general, a positive effect of external strengthening was defined, however, the tests also showed that the number of CFRP strips can be reduced and what are their recommended location as well as orientation in relation to bed joints.

3) Bamboo

Innovation in the form of structure and material usage have the potential to prevent over dependence on non-renewable materials like, sand, cement, and gravel that are used for construction. This will help to arrest the accompanying environmental degradation that accompanies extraction of non-renewable materials. The conventional concrete is strong but high in self weight. This factor effects construction time and the worker which will lengthen the construction period. The use of lightweight precast panel on wall and room divider is a mayor requirement for building industry. Precast walls are often used as a room divider in rental offices. The wall does not carry the vertical loads, but their own weight influences the mass of the building. Some walls designed to resist wind or earthquake loads. As room divider for the wall, the precast system is suitable choice. Although it more expensive than masonry wall, it can reduce the time construction required and amount of site lab works.

The lightweight panel is widely use in building infilled wall to reduce the building mass in lieu of brick walls. The present innovation works use bamboo and aerated concrete blocks into precast concrete panel. The average weight of the panel was 1650 kg/m3 compare to ordinary reinforced concrete 2200 kg/m3. Two type of panel dimension were used 40 cm x 80 cm x 3 cm and 60 cm x 120 cm x 4 cm. Bamboo reinforcement act as a structural framework of the panel and aerated concrete block (AAC block) functioning as infilled wall or cladding. Panels were loaded at the in- plane panels at two position, namely at the peak and at the middle panel height. When the load position was at the peak the average failure loads were120 N for small and large panel, the failure occurred at compression at top diagonal frame. when the load position was at mid panel, the average failure loads were140N for small panel and 260N for large panel, the failure occurred as shear cracks on the panel. The failure load of panel without aerated concrete blocks were130N for small panel and 215N for large panel.

IV. TEST PROCEDURE

1) Load bearing

To determine the influences in the masonry corner zone and setting the length of walls, by which cracking will not take place. In the opinion of the author apart from recalled higher influences from shrinkage deformations, the size of vertical loads, friction forces in the concrete-masonry joint and dimensions of the wall is also affecting no damage coming the diversified vertical lads from ceilings and the roof passed on to walls gathering in the corner and changes of thermal loads in different seasons.

In order to calculate the length of uncracked walls in ABC OBJEKT program the FEM three-dimensional model was built. The smallest objects, in which the size of vertical stresses in walls is much lower than the masonry compressive strength is exposed to the cracking. In such situations low friction forces are arising in the concrete-masonry joint and the effects for reducing shrinkage deformations are small. Therefore, a small object was analysed. It was calculated of a residential building with the functional attic. For analyses a connecting between gable wall and the oblong wall was accepted. It was assumed that the structure of the roof applies a load only an oblong wall, and the solid slab floor applies a load on both walls.

A symmetrical excerpt of a corner of a building was modelled (fig. 1). Two FEM models were made about diversified geometry. A relationship walls long was accepted equal of L1/L2 = 6/4 m (model I) and L1/L2 = 4/3 m (the II model). Both models are loaded:

q1 – roof loads (resulting from conducted separate calculations at establishing the wooden collar beam rafter framing, warming the roof, roofing with the ceramic roof tile and environmental loads),

q2, q3 – loads of oblong and gable walls,

q4 – imposed loads on floors,

q5 – self-weight loads of ceiling and floors, self-weight loads of ceiling and walls (accepted automatically in ABC OBJEKT program), shrinkage loads – 0.3 mm/m

q6 – friction forces in the concrete-masonry joint (friction factor they were accepted equal 0.7), loads from thermal influences. Heating the inside part of the walls to the +20°C and cooling outside to – 20°C, loads from thermal influences. Heating the inside part of the walls to the +20°C and outside to +40°C (load excluding each other from with the outline above).

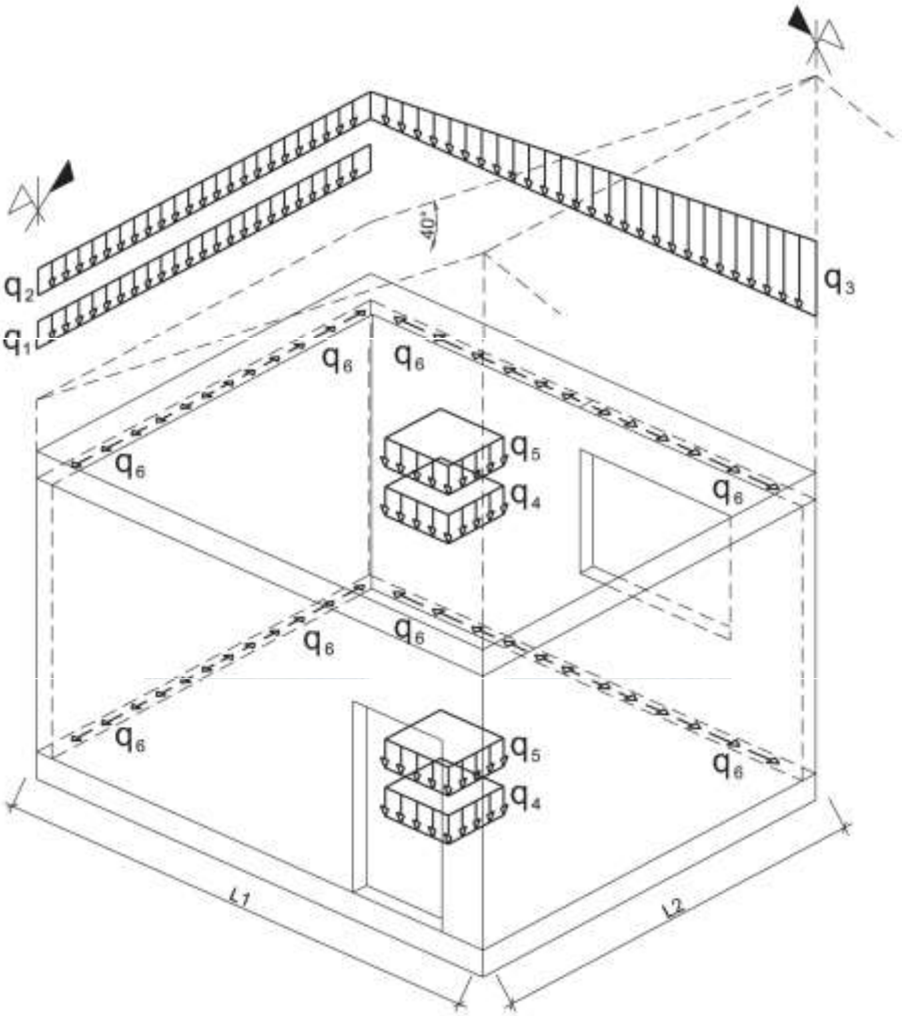

Fig. 1. Schematic model used for analysis

Calculations were conducted at accepting linear material characteristics of concrete and the masonry. Coefficient of thermal expansion was assumed on the level □t = 8·10 -6 /K. Value of the modulus of elasticity and the density of the masonry accepted based on conducted examinations [5]. Numerical models had appropriately to the size 1128 and 1926 finished elements. Thickening of elements was applied near the walls corner and at connecting the walls with ceiling. The model is not considering non-linear, material parameters of concrete and the masonry and the influence of unfilled perpend joints.

2) TEMPERATURE

The following materials were used for this study:

• AAC BLOCKS: Blocks manufactured using fine aggregates, fly ash by passing hydrogen gas where used for various tests. These AAC blocks of size 600mm×200mm×150mm.

• Ready JOINT MORTAR: Joint mortar proves to be good in bonding action when used with AAC blocks.

• MORTAR-READY PLAST: Plaster mortar proves to be good bonding and acts as an ideal plaster mortar when used with AAC blocks.

Following methodology was adopted to assess the performance of AAC blocks. In this regard a test program was planned and designed to carry out various studies based on the actual site conditions.

Case 1: Strength behavior of block specimens under varying temperatures.
Case 2: Bond behavior of masonry joints with varying mortar ratios and thickness.
Case 3: Crack behavior of prisms made with block specimens under varying temperature
Case 4: Thermal comfort studies of the AAC blocks in comparison with solid concrete blocks
Following tests were conducted based on the above-mentioned0020cases.

- Compressive strength test
- Behavior of bond with varying mortar types and thickness
- Crack visibility study
- Thermal comfort study

3) REINFORCEMENT

The test of walls subjected to vertical load and simultaneous deflection of the beam supporting these walls was carried out in a specially designed and constructed the test stand. The walls were built directly in the test stand on a slender steel beam supported at this time along the entire length. After the wall was erected, a prefabricated reinforced concrete rim beam was placed on upper surface of the wall on the layer of mortar. The vertical load *F* was realized by means of hydraulic jacks with a range of up to 500 kN. The *F* forces were measured using force gauges with a range of up to 500 kN. The load was transferred to the upper face of the wall via two I-section steel crossbeams. The vertical displacements of the steel beam supporting the wall reflected the movements of the real supporting structures such as floor system members, lintels, and foundations. The flexural stiffness of the supporting steel beam was intentionally small to allow for additional displacements beyond those resulting from the vertical load. The additional deflection of the structure supporting the masonry wall results from the loads directly acting on the floor (self-weight of floor and imposed floor loads) and could be the result of delayed deformations of the concrete (shrinkage and creep), which can be greater than elastic deformations even more than three times. Therefore, the deflection of the steel supporting beam δvi was implemented twofold. First, it resulted from the vertical load of the wall with *F* forces transmitted indirectly to the beam, considering the arch effect in the wall. Second, it could be increased to the value previously planned for a given phase of the test using a set of steel elements specially designed for this purpose, equipped with hydraulic jacks with a range of up to 150 kN and force gauges with a range of 50 kN and 100 kN. The displacements of the supporting beam were measured by means of displacement transducers with a measuring range of ±50 mm attached to steel angles connected to the outer supports of the test stand independently of the deforming beam. Vertical displacements were measured on both sides of the wall in 1/6 and 5/6 span length (displacement δv1), in 1/3 and 2/3 of the span (displacement δv2), and in the middle of the span of the beam (displacement δv3). The deflection planned in each test phase was fixed by means of M30 screws.

Besides of the values of *F* forces and vertical displacements of the supporting beam δvi, deformations of the walls were also measured along 11 measuring bases on both wall surfaces in two areas conventionally named "L" and "R". The horizontal measuring bases were 1890-mm long, the length of vertical bases was 1886 mm, while the length of diagonal bases was equal to 2670 mm. Changes in the length of the measuring bases resulting from the vertical load with *F* forces and deflection of the beam supporting the masonry walls was measured by means of displacement transducers with a measuring range of ±5 mm and ±10 mm. Based on the changes in the length of bases denoted with letters from *a* to *k*, the values of the deformation angles θi in the area "L" and "R" were calculated. It was assumed that the mean value of the deformation angle in the area "L" is the arithmetic mean of angles from θ1 to θ4 (in total eight values of angles determined on both sides of the wall), while in the area "R" it was the mean of angles from θ5 to θ8. For example, the angle θ4 was calculated.

4) CFRP STRIPS

Cracking of masonry walls made of AAC blocks with thin layer cement mortar and unfilled head joints is so common that researchers were forced to look for solutions to improve crack resistance of these structures to undesired external impacts. Current research in this topic is focused on strengthening with FRP materials. Fiber reinforced polymers are materials composed of high strength fibers, usually glass or carbon, submerged in a polymeric matrix. These materials exhibit high strength and stiffness with a favorable strength-to-weight ratio. It has been over 20 years now that Prestley and Seible [9] have written about possibilities of using FRP material for strengthening of structural elements. The first to present the advantages of superficial strengthening of walls with FRP laminates was Schwegler [10]. Following researchers [11,12,13] confirmed that such external strengthening with carbon fibers increase the resistance of the strengthened masonry walls. Another important aspect, apart from the choice of material (carbon or glass fibers), is a way of wrapping of the wall. Due to relatively high cost of the strengthening material, it is advisable to find an optimal layout of strip strengthening of the masonry wall (horizontal, vertical or diagonal). Extensive research of Santa Maria et al. and Mahood & Ingham [14,15,16] has shown that diagonal strengthening and strengthening perpendicular to the bed joint gives satisfactory results. Therefore, a research has been conducted for a couple of years at the Silesian University of Technology on the choice of the optimum method of external strengthening of masonry [17,18,19]. The results of these investigations are promising.

5) BAMBOO

Bamboo is now being used as a substitute for steel reinforcement. It has sustainable and renewable natural resources. The weight of bamboo is less than conventional steel reinforcement. The use of bamboo reinforcement has been developed by many researchers. [21], [22], [23], [24], [25]. [26], and [27]. The combination of normal concrete with lightweight material like an autoclaved aerated concrete block developed by Dewi [27] and the combination with expanded polystyrene or better known as Styrofoam developed by Wibowo [28]. In those combination normal concrete act as structural part and lightweight material act as a nonstructural infilled. The in-plane shear resistance of wall usually tested by applying loads at the top wall while the wall is fixed in the strong floor [29]. The load can either monotonically or cyclically. These papers present the study of precast light weight panel composite. The wall panel made from bamboo frame, the aerated concrete blocks, wire mesh and mortar.

V. RESULTS AND ANALYSIS

1) LOAD BEARING

Values of deformations and stresses in the model were analyzed. A double criterion to the crack formations was adopted: excess of masonry tensile strength and excess masonry shear stresses. The value of masonry tensile strength, by which cracks appeared in ACC masonry are equal of 0.2 N/mm^2. The value of masonry shear strength was established on the level 0.18 N/mm^2 based on research made in Silesian Technical University in Gliwice, partly published in [6]. Elements, in which value of masonry tensile strength and masonry shear strength were exceeded, were removed from the maps. Removed elements depict cracking areas of the wall. Reducing dimensions of the wall to 4.0 and 3.0 m results in reducing tensile and shearing stresses.

2) TEMPERATURE

Crack behavior of prisms made with block specimens subjecting to temperature cycle:

- To know the crack behavior, prisms were visually examined for appearance of cracks after subjecting to a temperature cycle i.e., 40^0C for 1hr and followed by 50^0C for 1hr and further 60^0C for 1hour.
- For the prisms plastered using ready joint mortar and ready plast mortar surface cracks started appearing after completing the 1 hr of exposure at 50^0c.
- Crack width of the same started increasing after exposing to 60^0c for 1 hr on the plastered surface.

- Where in the case of cement mortar plastering of 1 :3 ratio, no surface cracks were seen on the surface of prisms till 50^0c. But beyond this temperature, surface cracks appeared on the surface. However, this requires more test data.
- Table 1 gives surface crack behavior of prisms with different mortar types and subjecting to a temperature cycle

Table I: Surface crack behavior of prisms with different mortar types and temperatures.

Sl. No.	Type of mortar	Temp.in 0c	Surface cracks observed over plastered surface		Width of the crack (mm)
			No	Yes	
1	Ready joint mortar and ready plast	40	√		-
		50		√	**1.2**
		60		√	**2.5**
2	Cement mortar 1 :3	**40**	√		-
		50	√		-
		60		√	**1.2**

3) Reinforcement

The cracking pattern of all tested walls at the ultimate load and accompanying deflection of the supporting beam. In addition to detachment the walls from the beam, there were mainly multiple oblique cracks, vertical cracks in the area of the lower corners of the walls, and crushing of the masonry units in this area, and vertical cracks around the center of the wall length appeared. cracking pattern at the moment when the deflection of the supporting beam was equal to about 1/500 of its span, with the accompanying vertical load in the range from 353 kN/m^2 to 364 kN/m^2 and with deflection of 1/250 of the beam span and vertical load from 463 kN/m^2 to 532 kN/m^2. It is worth noting that the "stepped" diagonal cracks running only through the bed and head joints occurred only in the case of unreinforced walls. Relatively least cracks occurred in the walls reinforced with steel wire meshes.

4) CFRP Strips

Test specimens were made of AAC (autoclaved aerated concrete) blocks with thin bed joints and unfilled head joints. Both head sides of each block had gripholes. Density of AAC blocks was equal to ρ_v = 600 kg/m3 and compressive strength (mean tested value) was f_b = 4.65 N/mm2. Compressive strength of the mortar was equal to f_m = 12.4 N/mm2. The overall dimensions of all test specimens were identical and equal to 900 × 805 × 240 mm. The aim of the test was to investigate the effectiveness of strip strengthening with uniaxial CFRP mats. As a strengthening material, CFRP woven mesh was used with the modulus of elasticity of 120kN/mm2 and the mass of 290 g/m2. CFRP strips with the width of 150 mm were glued with resin epoxy glue.

Three series of test specimens were conducted:

- unstrengthened masonry wallettes – reference models – **NS** series.
- masonry specimens with strengthening strips covering unfilled head joints (two strips fixed to both sides) – **IIC** series.
- masonry wallettes with strengthening strips outside unfilled head joints (three strips from both sides) – **IIIC** series.

Each series consisted of 6 components.

Test specimens were subjected to diagonal compression according to the recommendations of RILEM LUMB 6 [20]. Inductive LVDT gauges were placed on both side surfaces of the wall (along both diagonals) to record vertical and horizontal displacements measured with the accuracy of 0.002 mm. The way in which the wall was placed in the test stand allowed vertical orientation of one of the diagonals. The wall was stabilized with steel shoes whose fitting covered approximately 1/10 of the length (height) of the specimens. A prepared test model was placed in a steel frame to stabilize the sample during axial compression. The walls were loaded in one cycle: from zero to failure. Load speeds for all tested models were identical and equal to approximately 0.1 kN/s.

State of cracking and ultimate stresses

During laboratory tests the compressive force and displacements were recorded, measured by inductive gauges. Table 1 shows the values of cracking stresses (τ_{cr}), the maximum shear stresses (τ_{max}) and the ultimate value of shear stress (τ_u) at failure. Additionally, the values of cracking stresses and ultimate stresses were compared in the strengthened (**IIC** and **IIIC**) and unstrengthened (**NS**) specimens. This comparison is shown in Table 2. In case of the unstrengthened walls failure was associated with the appearance of cracks. Average cracking tensile stress, equivalent to the ultimate stress at failure, was equal to 0.20 N/mm2. Cracks appeared at the similar level of stress in the wall strengthened with the strips outside the unfilled head joints (**IIIC** series), where the calculated values of cracking tensile stress (τ_{crIIC}) ranged from 0.16 to 0.22 N/mm2. In this case cracking stresses were not the ultimate stresses. An increase of 45% in the cracking stress was observed in the walls strengthened with the strips over the head joints (**IIC** series) comparing to the unstrengthened walls. Cracking stresses of **IIC** series ranged from 0.26 to 0.32 N/mm2 ($\tau_{cr,mv(IIC)}$ = 0.29 N/mm2). The highest, 90% increase of the load-bearing capacity of a masonry wall (τ_{max}) was observed in the masonry walls strengthened with the strips over the head joints (**IIC** series). The maximum stresses ranged from 0.32 to 0.42 N/mm2 ($\tau_{max,mv(IIC)}$ = 0.38 N/mm2). In this series a difference between the maximum stress and the ultimate stress at failure (in the last phase of the test – $\tau_{u,mv(IIC)}$ = 0.30 N/mm2) was observed. The value of the ultimate force for **IIIC** series was at the same time the maximum force, which corresponded to the stress $\tau_{u,mv(IIIC)} = \tau_{max,mv(IIIC)}$ = 0.35 N/mm2. Based on the results presented above it can be concluded that external strengthening has a positive effect on the behavior of AAC block masonry, as it ensures a two-phase work: up to cracking and then up to failure of the whole element. In case of the strengthened elements, after the first crack occurred there was a reserve of load bearing capacity of 31% and 84% for **IIC** and **IIIC** series, respectively.

5) Bamboo

Cracking in concrete is important to observe therefore the cause of failure can be known. When load acted in top position the cracks indicate the compression failure in bamboo frame. Then there was no different load value between small and large panel. When load acted in middle position the cracks indicate the combination of shear failure and compression failure. There was some different load value between small and large panel. The wire mesh covered the panel surface should reduce the mortar failure of the panel in loads contact.

VI. CONCLUSION

1) Load bearing

Conducted calculations showed that cracks in wall corner could take place a little bit earlier than it is given in the literature [1, 2, 3, 4]. Walls with the length above 4.0 m can already be exposed to the crack formations. Cracking is an effect of not only rheological deformations and the temperature, but also results from geometry and the way of walls loading [30]. On the base of conducted analyses, the limiting of shrinkage of AAC units before building them in into the wall is significant [7]. Because it is the only type of the load which we can affect. Units should be seasoned and packing them and sending to the building site directly after leaving the autoclave are inadmissible. It is important so that producers declare the value of the shrinkage of their elements based on conducted cyclically tests. This problem was indicated in the paper [8].

2) Temperature

The following conclusions have been drawn from the study.

Compressive strength of the blocks was drastically reduced when it is exposed to 150^{0}c followed by cooling the blocks to room temperature by immediately immersing in water. Almost 35% of reduction in strength was observed. Hence, during fire situations it is not recommended to spray the water directly on the AAC Block surfaces. Joint mortar thickness of 2mm is not recommended in case of lean cement mortar mix of 1:6. A minimum of 4 mm thick CM is preferred in case of 1:6 proportion used as a mortar joint. Surface cracks on the plastered surface were observed beyond 50^{0}c temperature. However, this requires more test data. Based on the limited studies conducted on scaled models AAC model shown better thermal comfort in comparison with the model with SCB i.e., cooler during daytime by 1-2^{0}c. [31]

3) Reinforcement

On the basis of tests of unreinforced and reinforced full-scale masonry walls made of AAC blocks with thin bed joins and unfilled head joints with reinforcement meshes of various materials placed in masonry bed joints, subjected to vertical compression and simultaneous vertical deflection of beam supporting these walls, carried out in described range, it can be concluded that[32]:

1. Reinforcement affects the increase of ultimate loads and deflections; the load-bearing capacity of the reinforced walls was at least 1.42 times higher than walls without reinforcement,

2. Ultimate deformations of reinforced walls, expressed in the form of deformation angles, were smaller than in the case of unreinforced walls; the ratio of the ultimate values of the deformation angles of the reinforced walls to the angles obtained in the case of walls without reinforcement was less than or equal to 0.59, and

3. At the deflection of supporting beam approximately 1/500 and 1/250 of its span and with the accompanying vertical load, deformations of the reinforced walls were also lower than in the case of them unreinforced counterparts: the ratio of the deformation angles of the reinforced walls to the angles obtained in the tests of walls without reinforcement was less than 0.66 at the deflection L/500 and not greater than 0.57 at deflection L/250.

4) CFRP Strips

The paper presents the results of experimental tests and analysis of the behavior of small walls made of AAC blocks with thin joints and unfilled head joints subjected to diagonal compression. A total of 18 specimens were tested, grouped in three series: elements without strengthening (**NS** - 6 pieces), with superficial strengthening covering head joints (**IIC** - 6 pieces) and with superficial strengthening outside the head joints (**IIIC** - 6 pieces). The aim of the study was to evaluate the effectiveness of two ways of superficial strengthening using CRFP mats. Both types of superficial strengthening have a positive influence on the mechanical properties of masonry walls and behaviour of the structure when subjected to shear. Testing of numerous samples (a total of 18 pieces) allowed to perform primarily a qualitative analysis but also a pre-quantitative analysis of the issue. Based on the results of the presented tests, the following conclusions could have been drawn[33]:

- Superficial strengthening of AAC block masonry wallettes has shown their multi-phase work, in contrary to the unstrengthened specimens where failure was purely brittle, caused by the appearance of the first crack.
- Modes of failure of the strengthened elements were safer because they were associated with excessive deformations (the width of cracks exceeded 10 mm, which was classified as undesirable) and progressive failure of the strengthening mesh, not a sudden failure of the entire structure;
- Superficial strengthening fixed on the head joints (**IIC** series) provided 45% increase of crack resistance in comparison to the unstrengthened wall; no increase of crack resistance was observed in **IIIC** series walls. It means that a better way of superficial strengthening is fixing CFRP strips covering the unfilled head joints, as it was done in **IIC** series.
- CRFP strips allowed for larger deformations of the masonry walls at failure.
- There has been a significant increase in the ultimate force destroying the strengthened walls. The load bearing capacity of the walls with strengthening over the head joints was as much as 90%, and that of the walls with strengthening outside the head joints was 75% higher than the capacity of the unstrengthened walls.

5) BAMBOO

1. The use of AAC should reduce the panel weight 18%
2. The failure of panel when loads in top position were compression at corner panel
3. When load position at the middle of panel, the shear failure and compression at load contact occurred.
4. There was no significant difference between lightweight panel load and normal concrete panel load.
5. For the next research, it is recommended to increase mortar strength and design the panels joints. [34]

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